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Response characteristics of the sensitive cup anemometer Type IV

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AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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Summary

Wind tunnel investigations into the variation of response of the sensitive cup anemometer Type IV (Plate 1), as made by Casella, with orientation relative to the wind have confirmed the existence of variations amounting to some 2 per cent of the response. Further variations due to the effect of the supporting mast normally used in fieldwork are shown to be of similar magnitude. Means of achieving greater accuracy are discussed.

Introduction

In the course of accurate measurements of wind gradient near the surface, where errors of 1 per cent or less become significant, a number of workers have noticed that the response of the sensitive cup anemometer is not constant at constant wind speed. In particular, N.E. Rider, School of Agriculture, Cambridge University, has observed anomalous points on his wind profiles which he ascribes to the fact that the corresponding anemometers were supported on the opposite side of the mast to the remainder.

There are three distinct effects which may occur: variation of response due to (1) varying the orientation of the contact housing relative to the wind direction; (2) varying the orientation of the supporting arm relative to the wind; (3) varying the distance of the anemometer from the mast. These will hereafter be referred to as effects (1), (2) and (3). In the field, of course, the three effects will be combined.

It was thought desirable to investigate the magnitude of these effects under controlled conditions in the wind tunnel and, in particular, to find out whether there is any way of using the instrument so as to reduce the errors to an acceptable level.

A number of experiments have been performed at Harrow to this end. Part I of this report deals with effect (1); the remaining effects are dealt with in Part II.

Part I - The effect of the contact housing

Experimental method

Two slightly different methods have been used, both employing an electrical contact anemometer (Crawford (1951)) and an open circuit wind tunnel whose working section has dimensions approximately $2\frac{1}{2}$ metres x $1\frac{1}{2}$ metres x 1 metre. Owing to the difficulty of maintaining a constant wind speed in the tunnel it was necessary to use a control instrument to monitor the wind speeds.

In the first series of experiments, a sensitive cup anemometer of the dial reading type was used for this purpose, the two instruments being placed

in line abreast at equal distances (30 cm) from the side of the tunnel. A pitot-static tube was used to obtain rough adjustments of the wind speed, and series of readings were taken at eight different orientations of the test instruments, and at several wind speeds. On reversing the relative positions of the anemometers the results obtained were of the same type as before.

Unfortunately it transpired that the anemometer under test possessed a time lag: it sometimes required a period of up to 20 minutes to settle down to a steady reading after re-orientation. This fault was ascribed to mechanical imperfections and was not found in five other anemometers tested.

For this and other reasons the first results were not considered reliable and a second series of tests was made, this time with a mechanically sound anemometer, calibrated in 1953. The instrument was supported in the centre of the working space and a N.P.L. calibrated airmeter was used as the monitor. The latter was supported in a position approximately 40 cm to one side and 15 to 20 cm to leeward of the anemometer.

In the main two wind speeds were used, 3 and 6 metres per second, but some observations at 9 and 12 metres per second gave almost identical results to those at 6 metres per second.

It was felt that the appropriate unit in which to express the response was that of counts per minute. For this purpose and to compensate for the variations of airspeed in the tunnel two observations were sufficient, namely (a) the number of counts made by the anemometer in the time required for the airmeter to complete a fixed run and (b) the amount of this time as measured by a stopwatch. These data were used to compute the number of counts per minute which would be registered by the anemometer at some convenient standard airspeed (very close to the nominal airspeed). The normal time for a run was about 8 minutes.

Results

The resulting response was plotted against the orientation expressed as one of sixteen points of the compass. Typical curves are shown in Fig.1. It was thought that the rather marked asymmetry shown in the 6 metre per second curves might be due to the influence of the anemometer on the airmeter readings, so the airmeter was moved to a similar position on the other side of the tunnel and further readings taken. No significant change in the shape of the curve was obtained, although its absolute value changed by about 0.3 per cent.

The observational uncertainty in each reading may be taken as about 0.2 per cent at 6 metres per second and about 0.3 per cent at 3 metres per second, and systematic errors of a similar magnitude may be present owing to the various tunnel effects. The latter, however, are unlikely to affect the actual shape of the curves.

Further tests with an anemometer supplied by N.E. Rider give closely similar results, though rather more asymmetry was observed at 3 metres per second and the variation of response with orientation was 0.5 per cent greater. This agrees approximately with Rider's own estimate.

As a control experiment a cylindrically symmetrical cover was made, of the minimum size, and placed over the anemometer housing. No significant variation of response with orientation could then be observed.

Discussion

Let us consider in turn the two main aims of the investigation.

(a) Determination of the magnitude of the errors. It can be said with some confidence that, on the average, effect (1) gives rise to a range of response of about 2 per cent over the 360° range of orientation. But this figure will vary, certainly by 0.5 per cent and possibly by more, from anemometer to anemometer and wind speed to wind speed.

It is clear, however, that in the field, with a fixed length of supporting arm, effects (1) and (2) will combine, and not necessarily in a simple manner. It is possible (see Part II) that the combined error could in some cases reach as much as 4 per cent.

(b) Methods of reducing errors to an acceptable level. Considering effect (1) alone, the only hope of using the present type of anemometer successfully for highly accurate work in the field would be to use it in the orientation for which it was calibrated and to choose this orientation to lie on a sufficiently flat part of the response curve. Whether this is possible in a particular case will, of course, depend on the degree of accuracy desired and on the nature of the response curve. The other alternative is to redesign the anemometer so as to be cylindrically symmetrical. It should then be possible to apply an independent correction for the combined effects (2) and (3) or to make them small by using a somewhat longer supporting arm than is the custom at present (see Part II).

The ideal solution would be to have the cup assembly rotating about the mast itself, but this would appear to be impractical owing to excessive friction in the bearings.

Part II - The effect of the supporting mast

Experimental method

An open-circuit wind tunnel and an electrically indicating anemometer were used, with an airmeter to monitor the airspeed. The anemometer under test was supported throughout in the centre of the working space to minimise uncertainties due to wall-effects.

Effect (2). In order to simulate as far as possible the effect likely to be obtained with a symmetrically designed anemometer, a large circular disc was placed horizontally just above the dial housing as indicated in Fig.2.

Eight positions of the mast relative to the wind were used, numbered as in Fig.2(b). When the mast was in one of the positions 3, 4, 5, 6 or 7 the airmeter was placed as shown in Fig.2(b). For positions 7, 8, 1, 2, and 3 it was placed correspondingly on the opposite side of the system. Thus two readings in each of positions 3 and 7 were obtained and the (small) difference could be taken into account in setting out the response curves.

The quantity actually observed was the number of counts made by the anemometer in the time required for the airmeter to complete a fixed run (in feet of air). The latter was chosen so as to give between 600 and 700 anemometer counts at each of three wind speeds, and was 5,000 ft in each case.

As a rough check on the results obtained by this method, a similar experiment was carried out in the absence of the large disc, using positions 1, 3, 5 and 7 of the mast, but still keeping the anemometer contact housing fixed in the upwind direction. The same type of variation was obtained as with the disc, though the actual number of counts per run was increased.

By fixing the standard ten-inch supporting arm just below the anemometer and removing the mast, it was shown that no part of effect (2) was due to the supporting arm. That is, the response showed no measurable variation with orientation of the supporting arm in the absence of the mast.

Effect (3). This effect was investigated only for orientations 1 and 5 of the mast. The horizontal disc was not used, and the anemometer itself was kept pointing upwind. The only variable was the distance of the mast from the anemometer which ranged from six inches to twenty inches.

3, 6 and 9 m/s were the wind-speeds used, and the method of observation was that described above.

Results

The magnitude of effect (2) is shown graphically in Fig.3 for wind speeds of 3, 6 and 9 m/s. Instead of expressing the results in counts per minute at a standard airspeed, the actual number of counts made during a fixed airmeter run was plotted as a measure of the response. The latter quantity is directly proportional to the former within the experimental error.

The pecked base-lines represent the response obtained with the disc in place but without the mast.

The observational error may be taken as 0.2 per cent, but the errors due to tunnel effects, position of airmeter, etc. are probably rather larger than this (0.3 per cent to 0.8 per cent) and impossible to assess accurately. Consequently the curves are to be regarded as giving a reliable qualitative picture of the effect, though only an approximate quantitative picture. It is encouraging to note that this picture is in good agreement with some observations made by Rider using a different experimental arrangement.

Fig.4 illustrates the third effect. Over much of the range the 6 m/s and 9 m/s curves were practically identical and are shown for convenience as one curve. Response, as measured by the number of counts per fixed airmeter run, is plotted against distance of the anemometer from the mast in inches. For ease of comparison the curves have been plotted relative to a common baseline representing the response of the anemometer in the absence of the mast.

The experimental error in this case may be taken as about 0.3 per cent.

Discussion

In Part I it was suggested that the only satisfactory solution to the problem of effect (1) was to redesign the instrument to be cylindrically symmetrical. It was also pointed out that effect (2) might be made small by increasing the length of the supporting arm, that is by making use of effect (3).

The results of the present investigation, as far as they go, show that there is every hope that this should be possible. It would seem that the supporting arm would need to be of the order of 18 inches in length for a mast of 1 inch thickness. More detailed wind tunnel experiments, using a redesigned anemometer, would be necessary to confirm this point.

Reference

Crawford, S.G. J. Scient. Instr., 28, p.36, 1951.

"A simple form of sensitive electric contact cup anemometer".

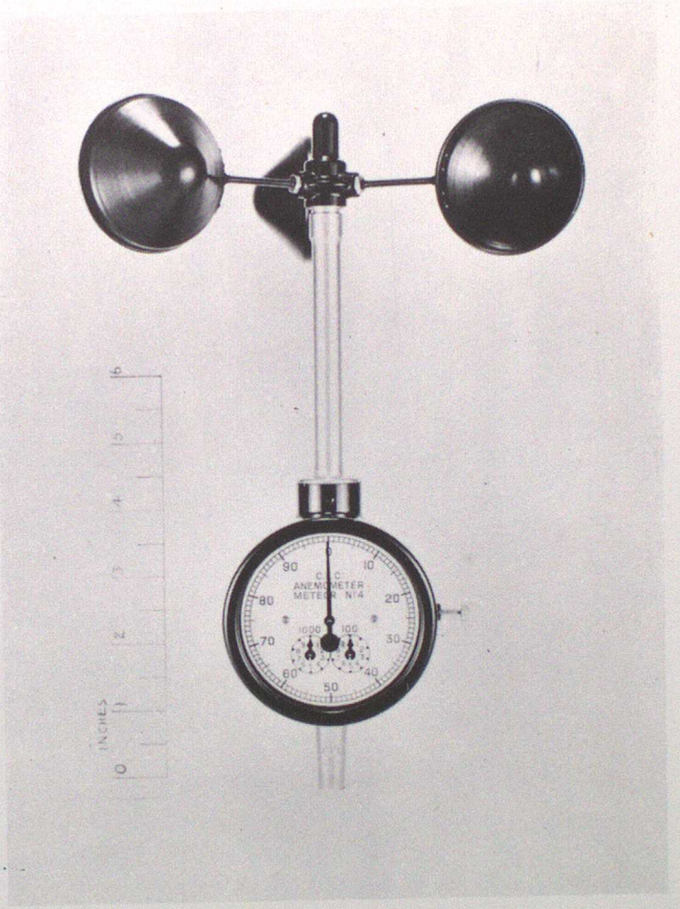
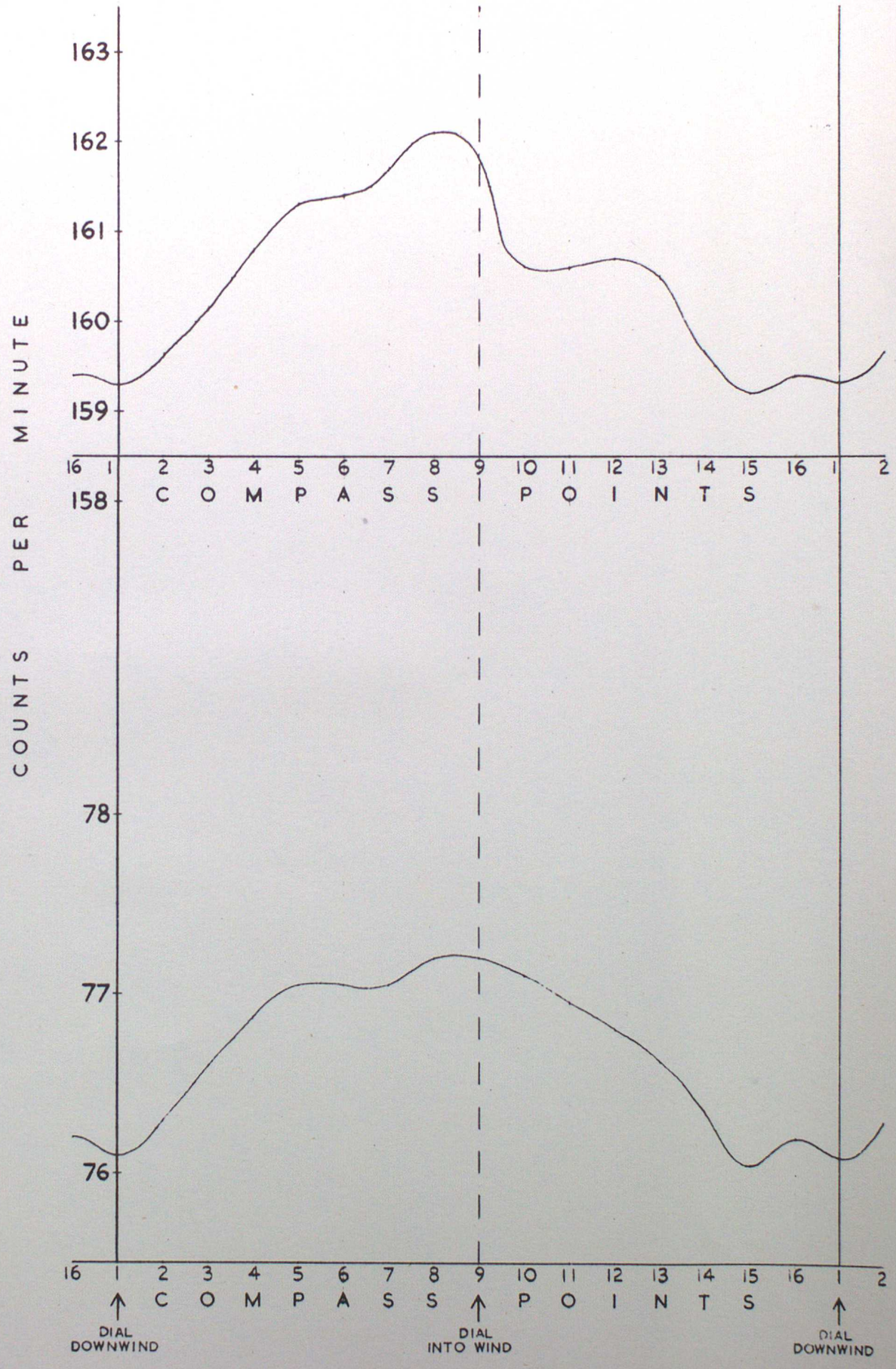


Plate I. Sensitive cup anemometer
Type IV

FIGURE 1. RESPONSE CURVES OF ANEMOMETER M.O. No. 46

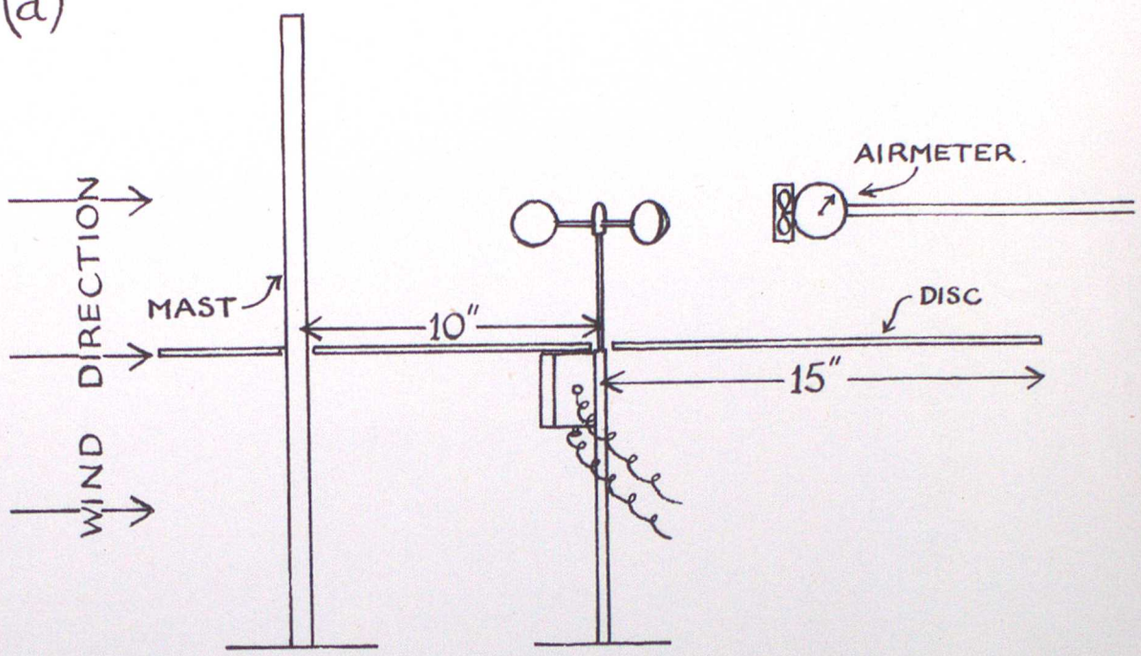
(a) WIND SPEED 6M/SEC. (b) WIND SPEED 3M/SEC.



DIAL ROTATED CLOCKWISE FROM ABOVE

FIGURE 2 For explanation see text, Part II.

(a)



(b)

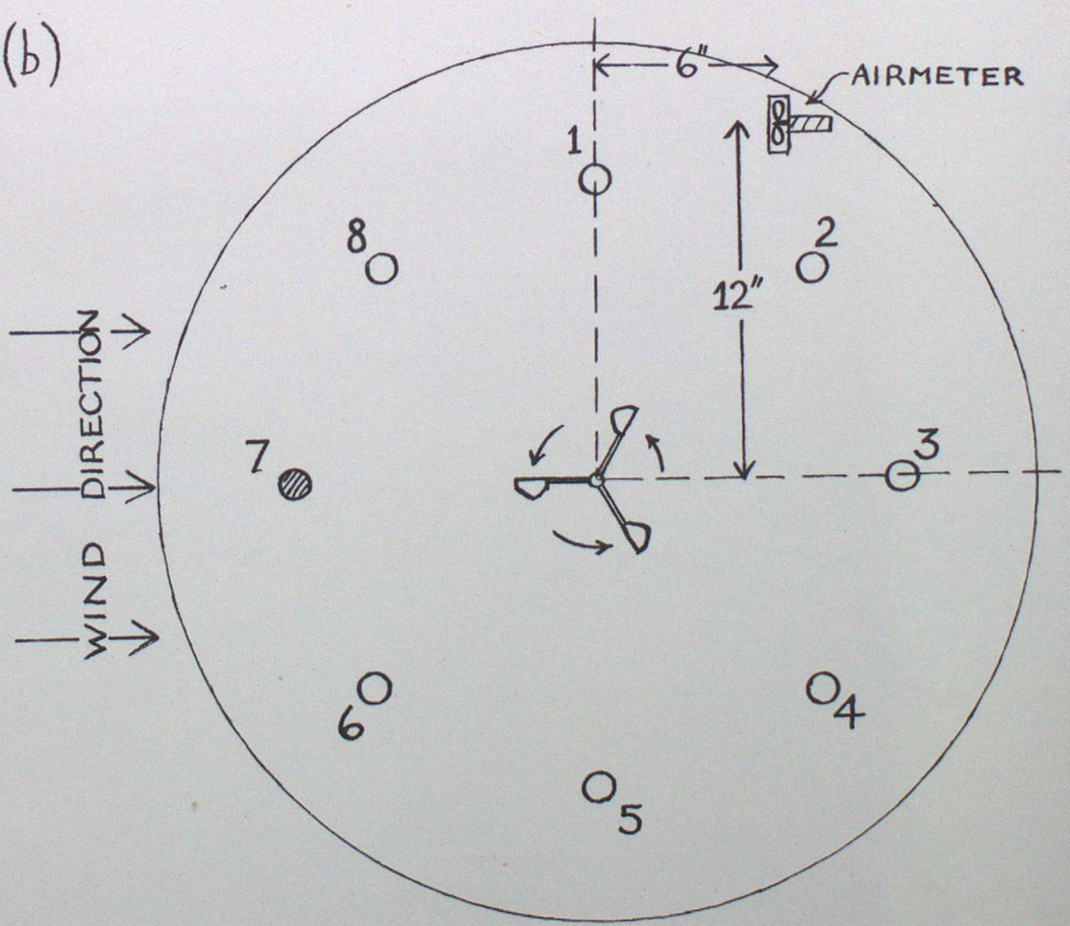


FIGURE 3.

EFFECT OF MAST ON RESPONSE OF ANEMOMETER M.O.46.

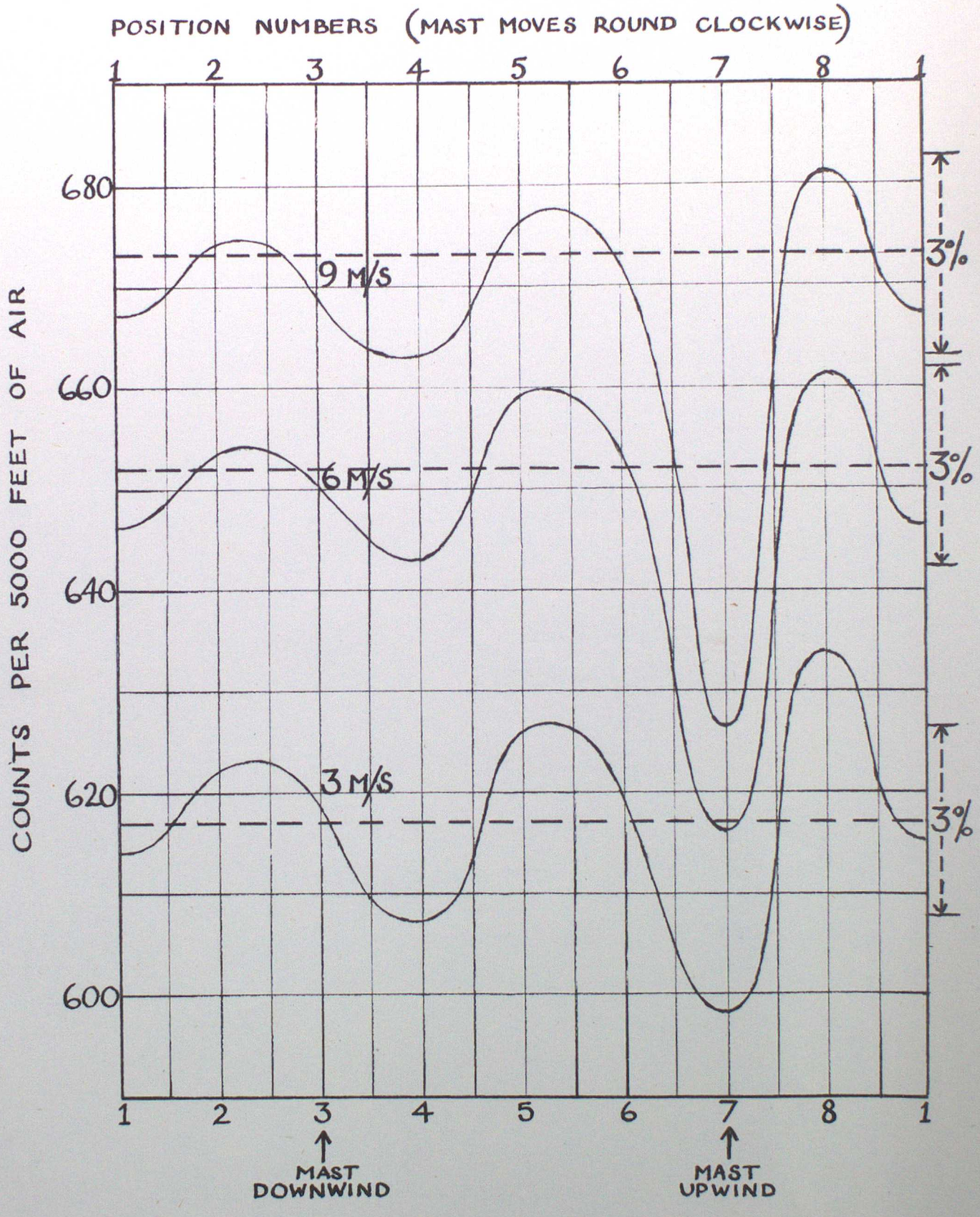
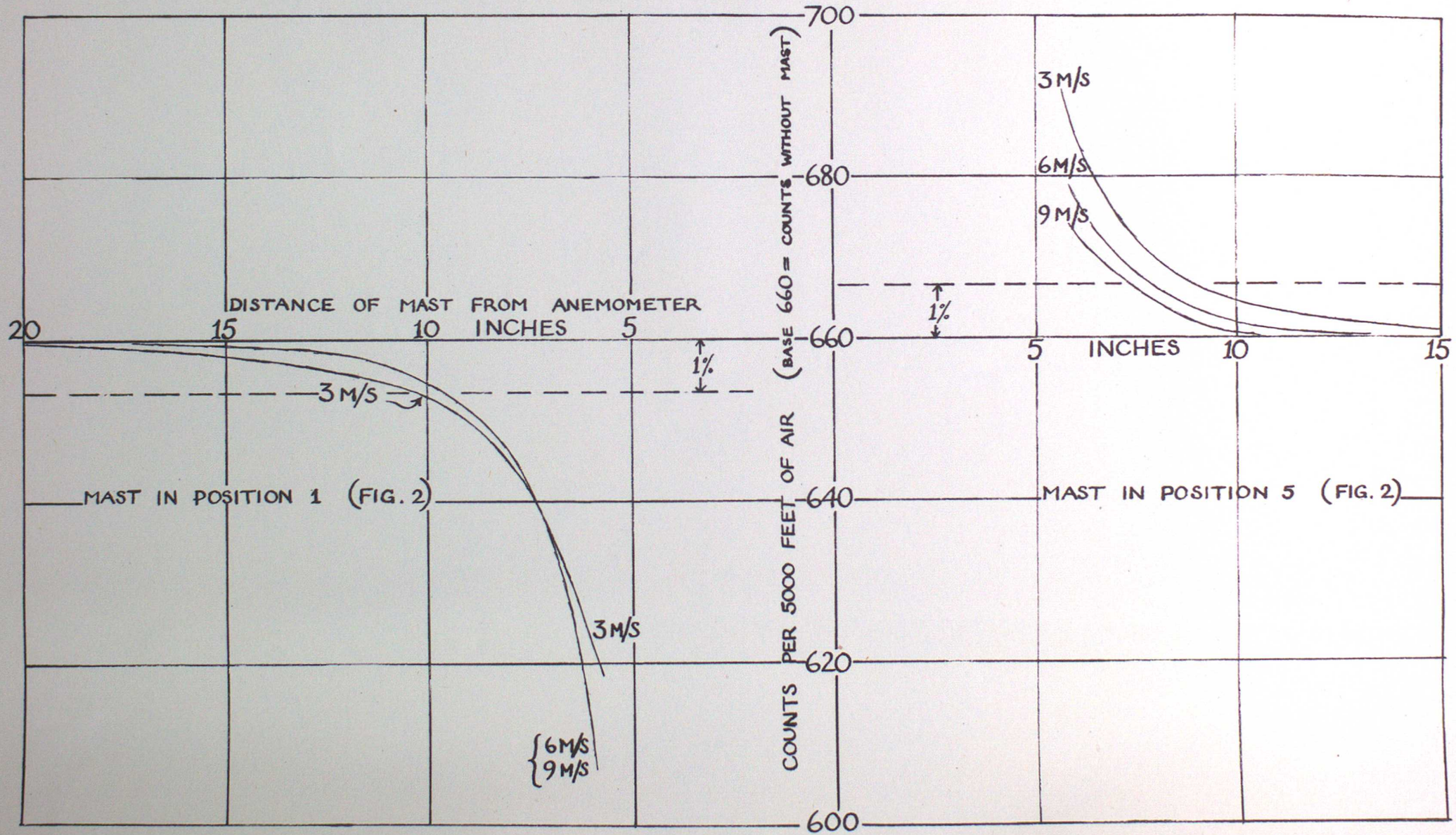


FIGURE 4.

EFFECT OF VARYING ANEMOMETER — MAST DISTANCE.

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